2D-SEISMIC INTERPRETATION AND PETRO-PHYSICS ANALYSIS OF CHAK NAURANG AREA, POTWAR SUB BASIN, UPPER INDUS BASIN, PAKISTAN

By

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CERTIFICATE

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"In the Name of ALLAH, the Most Merciful & Mighty"

"PAY THANKS TO ALLAH EVERY MOMENT AND GO TO EXPLORE THE HIDDEN TREASURES, ITS ALL FOR YOUR BENEFIT"

(AL-QURAN).

DEDICATION

I would like to dedicate this thesis work to my sweet parents, whose love, encouragement, guidance and prays make me able to achieve such success and honor.

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First and foremost, all praises to Allah Almighty, the most beneficent and the most merciful. Secondly, my humblest gratitude to the Holy Prophet Muhammad (Peace Be upon Him) whose way of life has been a continuous guidance and knowledge of humanity for me. This thesis appears in its current form due to the assistance and guidance of several people. I express my profound sense of reverence to Dr. Shahid Iqbal who gave me the opportunity to work under his supervision. His continuous support, motivation and untiring guidance have made this thesis possible. His vast knowledge, calm nature and positive criticism motivated me to starve for pleasant results. I am very thankful to Directorate General of Petroleum Concession and Landmark Resources for providing dissertation data. I am very thankful to Honorable Chairman Department of Earth Sciences Dr. Aamir Ali. Thanks to him for bearing my mistakes and whenever I could not meet the deadlines. I am forever grateful to my other professors for their help and suggestions during my work. I do express my sincere thanks to Shoaib Ata, Farman khan, Hashim khan. Abdul Wahid, Junaid Shah and Zahid khan for their good friends, so great pride is with me while Thanking my friends Words are lacking to express my humble obligation for their helping attitude, and kind Cooperation. The time spent with them will remain unforgettable for me. Finally, I would like to acknowledge my family for their constant support, unceasing prayers, and best wishes. They uplifted my moral whenever I needed. I do thank all those who have helped me directly or indirectly in the successful completion of my thesis. Anyone missed in this acknowledgement are also thanked.

GOHAR AYUB KHAN (NOVEMBER 2020).

Abstract

The dissertation pertains to investigate the 2D seismic interpretation off seismic lines 881-CW-11,782-CW-27 782-CW-28 and 782-CW-24 of Chak Nauran. To carry out this exercise, seismic reflection data, Which consist of line 881-CW-11,782-CW-27, 782-CW-28,782-CW-24 of Chak Naurang area situated in Potwar Fold and Thrust belt, data was recorded and proceed in 1988 by OGDCL and POL.The data passed through a desirable processing sequence and finally a time section was prepared.

Chorgali Formation, Sakesar Formation and Khewra Formation are main reservoir rocks and are productive in the Potwar Fold and Thrust belt. The study area is mainly characterized by compressional regimes, as there are major faults. Time controller map shows presence of anticlinal structures in Khewra formation. So, this may act as trap for hydrocarbons.

Three horizons are marked due to their prominent reflection on the seismic section namely Chorgali, Sakesar and Khwera respectively time section is prepared by using two-way arrival time from seismicGF section.

The petrophysical analysis of Chorgali show on prospective zone from 2617-2622 meters. Rock physics further confirms the presence of zone of interest.

Contents

CHAPTER 01

INTRODUCTION

1.1 Introduction

Indus basin stretches from the Himalayan mountains in the north to the plains of Sindh in Pakistan in the south and finally plans out to the Arabian sea. Its Northern part is considered to the upper Indus basin. Thus, include some parts of High Sargodha and part of punch outs and potwar Kohat plateau. Surveys were carried out, as a result, huge discoveries of hydrocarbons has made in these areas. The area is further divided into many structural-tectonic parts; the southern part named Salt range, the western part named Kohat plateau, the central part named potwar plateau, Besides these, along the northern side of the area including Folded zone and Chita fold belt.

1.2 Study area

The researcher study area is Chak Nuarang which is located at upper Indus basin. It is defined by computing regime and measured between Latitude 33`10'12"N and longitude 73'10'05".

To carry out a seismic study of this area is very hard task because this area is very complicated. The absorption of hydrocarbons in this area is very high. Thrust related Structural like arise, two-fold and anticlinal traps are familiar in this area.

1.3 Data obtained for study

The data was first recorded and process by OGDCL and POL. Auxiliary line was also used for interpretation. 2-D Seismic interpretation of Chak Naurang of Punjab unit was also used for interpretation. 2D seismic interpretation of the area has been carry off with the target to outline the subterranean structures and find out zones in perspective. In this area interpretation of seismic lines 881-CW-05, 881-CW-06, 881-CW-07, 881-CW-08, 881-CW-09, 881-CW-11, 782-CW-24, and 782-CW-27 were carried out. These lines were shot during the seismic survey conducted by OGDCL in 1988. The purpose of the survey was to locate the prospective zone in the anticline of Chak Naurang to understand the role of fault propagation folds in hydrocarbon entrapment. In order to get these objectives a new way of interpretation is carried out of the following seismic lines

1.4 Reflections data for seismic lines

S.NO	LINE NO	NATURE
1	881-CW-11	STRIKE LINE
2	782-CW-28	STRIKE LINE
3	782-CW-24	DIP LINE
4	782-CW-27	DIP LINE

Table 1.1: Trends of seismic lines

WELL INFORMATION

AMIRPUR-01
OIL AND GAS

1.4.1 Data Formats:

Seismic reflection data which consist of

- SEG-Y
- LAS
- NAVIGATION
- Velocities input from hard copies

1.5 Base map of the study area:

Base map serves as reference MA on which the main data and visualize geographical information can be plotted. Base maps contain information that may give the various geospatial information. Base map mainly provides location references for features that do not change like boundaries, rivers, lakes, road, and highways. It also provides geographic reference such as latitude and longitude, concession boundaries, wells, seismic survey pint etc. are also included.

The base map is the area resulted in by putting data in universal Transvers Mercator zones (UTM ZONES). The base map of fig 1.1 shows the aspects of the lines present in Chak Naurang area.

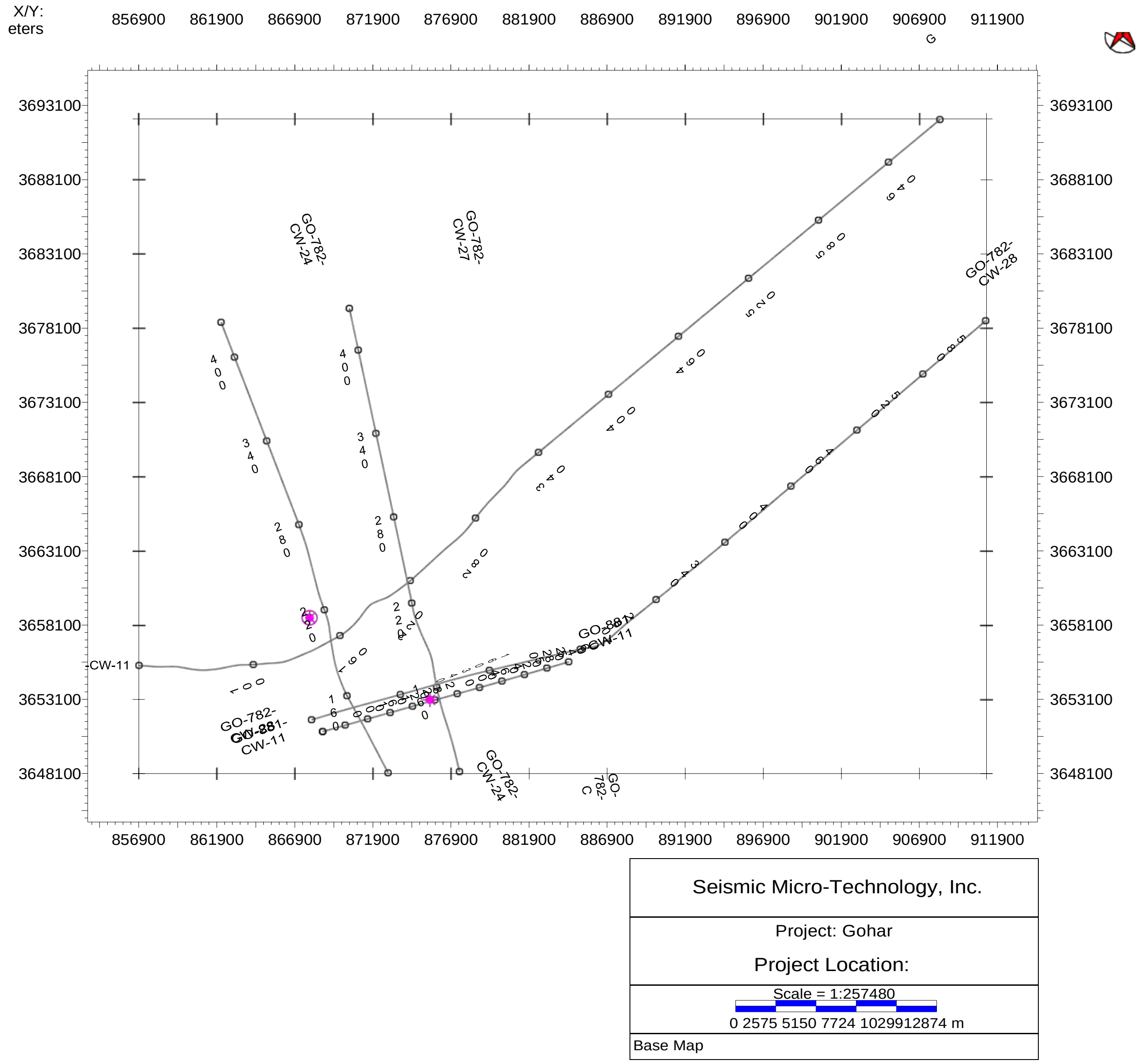


Figure 1.1 Base map

1.6 Objecectives

Preparation of time section

- Structure interpretation of the subsurface using seismic data
- Preparation of the time contour map based on seismic data
- To develop an understanding of tectonic and structural framework of the area.
- Petrophysical analysis
- Rock physics

CHAPTER 2

GEOLOGY AND STRATIGRAPHY

Geology of an area plays a paramount role in the exact interpretation of a seismic data.

In the same degree one velocity effect can be create from the formation of different lithology.

Similarly, different velocity formation can be created from sum lithological horizon.

Subsequently, if we do not know about geology of an area, we are unable to know the different reflective aspects appears in the seismic reflection

2.1 GEOLOGICAL AREA OF POTWAR PLATEAU

Photowar or potwar is a plate located at north-eastern Pakistan. Shaping northern part of Punjab. Khyber Pakhtunkhwa contains its southern part and azad Kashmir border thewestern part of it. the eastern side is limited by river Jhelum, the western side by the Indus river, the northern by the Kala Chita rang and by the Margalla hills. The southern side is bounded by salt range. The outlying Potwar Plateau bounded on the South by Salt Range Thrust (SRT), present the marginal foreland fold-and the thrust belt of the Indo-Pa Subcontinent, equivalent to sub-Himalayas in India (Pennock et al,1989).

2.2 STUDY AREA (CHAK NURANG)

Chak naraung is located at potwar plateau sub basin. It is determined by main boundary thrust (MBT) and Kala Chita range in the North. The southern side is bounded by Salt range. The ancient Miocene -Pliocene rocks famous as Nagri formation and Chinji formation are uncovered in the core of the structure and its border. A prominent thrust cum tear fault known as Chak Naurang Fault Wari through the area (1986). fault is passing Eocene Paleocene and Permian shales are the potential significant area of source and cap rock.

2.3 GEOLOGY OF PAKISTAN:

Geology of Pakistan overlaps with Indian and Eurasian plate. The geological division of Pakistan is related to the main subdivisions Laurasia Tethyan and Gondwanaland (Kazmi et al 1997).

The origin of this Area is considered to the late Paleozoic the passage of time, all the continents come together to form the bigger continent Pangea. After some more years the Laurasia moves to the North and Gondwana to the South. It is separated by Tethys Seaways. This phenomenon splits up the Pangea in to two parts.

Foreland-Fold and thrust comprises features of convergent continent plate boundary and NH Himalayan fold and thrust belt is characterized by numbers of faults. Himalayan mountain range considered to be the youngest mountain range formed recently. In Northern Pakistan There are three mountain ranges.

- Hindukush
- Karakorum
- Himalayan

Geographically the two rivers Hunza and Indus separates them he ranges in the west of Hunza river are Karakorum, between Hunza and Indus River are Hindukush range and in the west of Indus river Himalayan are located (Kazmi, 1997).

2.3.1 GEOLOGICAL DIVISION OF PAKISTAN

- Northwest Himalayan and thrust belts
- Indus Plate Form and Fore deep
- Kohistan Ladakh Magmatic are
- East Baluchistan Fold and Thrust belt
- Kakar Khorasan Flysch Basin and Makran Accretionary Prism
- Chagai Magmatic Arc
- Karakoram Block
- Pakistan Offs shore

2.4 MAJOR STRUCTURES IN STUDY AREA:

Major structures in the study area are

- JOYA MAIR ANTICLINE
- CHAK NARANG ANTICLINE
- DIL JABBA ANTICLINE

2.4.1 JOYA MIAR ANTICLINE:

JOYA MAIR ANTICLINE (Fig 2.2) is doubly plunging anticline and plunges 10 southwest and 4 northeast. The fold axis of anticline trends northeast-southwest and is cross-folded to form northwest-southeast trending Joya Mir antiformal syncline. The chinji Formation is exposed is the core and the Nagri Formation lies along the limbs. The geologic, structural, borehole and seismic data shows the that the Joya Mair structure is a triangle zone in the subsurface. The north western and southeaster limbs are faulted along the Meghan and Joya

Mair thrusts, respectively. These adults are steeper and district in higher and lower levels, respectively. The triangle zone is the result of southeast and northwest directed Himalayan thrusting. The Joya Mair triangle zone lies in the Southern Potwar Platform Zone and is segmented along the left lateral Vairo and Dhob Kalam faults (sham and Big,2003).

2.4.2 CHAK NAURANG ANTICLINE:

Chak Naurang Anticline is an example of a fault population fold. This southward verging anticline has two limbs, a steeply dipping, southern limb and moderator dipping northern limb. No fault has been mapped at the surface. Reflection data shows a strong northward-dipping basement reflector overlain by a thick evaporate section. Above the evaporates the strongly reflective platform sequence is offset and fault appears to lose displacement up section the Rawalpindi and Siwalik Molasses' (Pennock et al., 1989)

2.4.3 DIL JABBA THRUST:

Dill jabba thrust is a passive proof thrust south of Chak Naurang anticline in the eastern potwar plateau and is a hinterland-dipping fault rather foreland. At its southward terminus, the Rawat fault dies out along the southern flank of the Chak Belie Khan anticline and to the northeast it dies out near the Soan syncline axis (Pennock et al,1989).

2.5 HYDROCARBON POTENTIAL IN THE AREA:

The Potwar basin is one of the oldest provinces of the world. The first commercial discovery was made in 1914 at Khore (Moghal et al 2003). The eastern potwar region is an important oil and gas producing area. The oil and gas discoveries in the eastern part of the potwar plateau, located at the southeast of Soan syncline are mostly from NE-SW elongated anticlines. The Eocene to pre-Cambrian platform deposits are about 400m thick in the eastern potwar area. To date, more than 50 exploration and production wells have been drilled in the eastern potwar throughout the eastern potwar, oil production has been established from Eocene Permian and Cambrian age rocks. Exploration in the potwar began by drilling simple surface anticlines

Balkassar, Joya Mair and Chak Naurang were the producing oil fields since the independence of Pakistan. The Mirpur 01 well is exploratory well.

Hydrocarbons traps were probably developed in anticlines and thus the perspective zones for hydrocarbons in Chak Naurang and Joya Mair area.

Furthermore, on the basis of this seismic and structural studies and correlating the results with available gravity and magnetic data.it is concluded that Joya Mair thrust and Mangan thrust deformed the structural trap in Joya Mair area.it also indicates that Joya Mair anticline is not a single, structure rather it is faulted into blocks. That is why the expected reserves potential of Joya Mair Oilfield are not recovered so far.

The Salt Range Potwar Foreland Basin (SRPFB) has several features suitable for hydrocarbons accumulations including continental margin, thick marine sedimentary sequence, potential sources, reservoirs and cap rocks. The SRPFB with an average geothermal gradient of 2 degree/100 m is producing oil from the depth of 2750-5200m thick.

2.6 PETROLEUM PROSPECTS:

Following is the petroleum play in Eastern Potwar area.

2.6.1 SOURCE ROCKS OF POTWAR ROCKS:

The source rock oil correlation study is not carried out in the research that could have enabled us to identify and characterize the source rock of the field with confidence However Hydrocarbon Development Institute of Pakistan(HDIP) is collaboration with Federal Institute for geosciences and Natural Resources Hanover Germany have identified a number of source rock horizons through infra-Cambrian to Eocene in the Potwar basin and surrounding areas. These investigation imply that the organic rich shales of the Paleocene (Patala formation) can be considered as the main formation which is acting as source to the Potwar basin (Bender and Raza ,1995).Also Salt range Formation (Pre Cambrian) contains oil shale intervals ,which shows source rock potential (Porth And Raza 1990).

The oil to source correlation indicates that most of the oil produced in Potwar basin has been sourced through Patala Formation. Khewra shales of lacustrine to marine origin , containing woody, coaly to amorphous kerogen, which can generate, paraffinic to normal crude oil and gas.

The grey colored of the Mianwali,Datta and Patala Formations are potential source rocks in SR/PFB.The oil shales of the Cambrian Salt Range Formation include 27% to 36% TOC in isolated pockets of shales and are considered as the source rock in SRPFB (Khan & Raza 1986).

2.6.2 RESERVIOR ROCKS:

The Cambrian, Permian, Jurassic, Paleocene and Eocene are producing oil in SRPFB.The fractured carbonates of the Sakesar and Chorgali formations are the major producing reservoirs in the upper Indus Basin.

2.6.3 CAP ROCKS:

The Gondwana Formations acts as a cap for the reservoirs of Chorgali and Sakesar Limestones in the SRPFB.The clays and the shales of the Murree formation also provide efficient vertical and lateral seal in the Eocene reservoirs in SRPFB (Shami &Baig,et al 2003).

CHAPTER 03

SEISMIC INTERPRETATION

3.1 Introduction

Interpretation is an instrument to convert the entire seismic information in to structural or stratigraphic model of the earth. Since the seismic section is the representative of the geological model of the earth, by interpretation, we try to locate the zone of final anomaly. It is the rare that correctness or incorrectness of an interpretation is ascertained, because the actual geology is rarely known in well manner. The test of good interpretation is consistency rather than correctness. Not only a good interpretation be consistent with all the seismic data, it also important to know all the area, including gravity and magnetic data, well information, surface geology as well as geologic and physical concept (Telford et al, 1999).

Conventional seismic interpretation implies the picking and tracking laterally consistent seismic reflectors for the purpose of mapping geological structures, stratigraphy and reservoir architecture. The goal is to detect hydrocarbon accumulations delineate their extent and calculate their volumes. Conventional seismic interpretation is an art that requires skill and thorough experience in geology and geophysics.

To meet the challenges of exploring ever increasingly complex targets, there have been tremendous advancements in data acquisition equipment, computer hardware and seismic processing algorithm in the last three decades. The seismic method has thus, evolved into computationally complex science.

The computer-based working (Processing & interpretation) is more accurate and precise, efficient and satisfactory which provides more than one further analysis of the data. This whole work is carried out using a combination of computer software products, which include all Kingdom software and Tec log.

Our main purpose is to make reflection as clear as possible the structure and stratigraphy of the subsurface. Geologic meaning of the reflection is indication of the hydrocarbon where there is a change in acoustic impedance

to distinguish the different horizons with the seismic data we correlate the well information with seismic data has been interpreted with the well control and the well information is used to tie with the seismic data. Structure and estimate of the depositional environment, seismic velocity, seismic stratigraphy and the lithology is identified by using the best available seismic data (Dobrin & Savit. 1988)

There are two main approaches for the interpretation of seismic sections

- Structural Analysis

identification of structural features

- Stratigraphic Analysis

identification of Stratigraphic boundaries

3.1.1 Structural Analysis:

This type of analysis is very suitable in case of Pakistan, as most of the hydrocarbons are being extracted from the structural traps. It is study of the reflector geometry based on reflection time. The main application of the structural analysis of the seismic section is in the search for the structural traps containing hydrocarbons. Most structural interpretation was use two-way reflection times rather depth and time structural maps are constructed to display the geometry of selected reflection events. Some seismic sections contain images that can be interpreted without difficulty. Discontinue reflection clearly indicate faults and undulating reflection reveal folded beds (Sheriff, 1990).

3.1.2 Stratigraphic Analysis:

Seismic stratigraphy is used to find out the depositional process's environmental settings, because genetically related sedimentary sequence normally consists of concordant strata that show discordance with sequence above and below it. It also helps to identify formations, Stratigraphic traps traps and unconformity. This method also falciform the identification of the major progradation sedimentary sequence which offer the main potential for hydrocarbon generation and accumulation Stratigraphic analysis therefore greatly enhances the chances of successfully locating hydrocarbon trap in sedimentary basis environment.

3.2 Naming of Horizons:

Three horizons are marked on the seismic section based on continuity in reflection on the seismic section. Well tops are used in order to name the horizon. Amirpur-01 well lies at the distance of about 4 km from the vibrioses point 230 of seismic section 881-CW-11 whose well tops i: e actual depth of each reflector, are used for this purpose. Through the correlation of well tops and synthetic seismogram of well Amirpur-01 the reflectors are given the names. No reflectors are marked in the upper part of the section because reflection is not clear there.

Then by using the relationship: D=(Vav*T) /2 where,

D=depth of reflector in meters

Vav=mean average velocity meter per second

T=Two-way travel time in seconds.

These times were converted into depth. Then after the depth conversation the reflectors were given names, with the help of well tops of well Amirpur-01. The well tops of Amirpur-01 were given in the table 3.1

No	Name of Formation	MD(m)
1	NAGRI	0
2	CHINJI	543
3	KAMLIAL	1485
4	MURREE	1605
5	CHORGALI	2605
6	SAKESAR	2570
7	NAMMAL	2690
8	LOCKHART	2715
9	LOCKHART	2724
10	HANGU	2738
11	SARDHAI	2747
12	WARCHA	2781
13	DANDOT	2806
14	TOBRA	2833
15	BAGHWALA	2843
16	JUTANA	2853.5
17	KUSSAK	2878
18	KHEWRA SANDSTONE	2953

Table 3.1

3.3 Procedure of interpretation:

The 2-D seismic structure interpretation which has been used in the dissertation is done based on available information and stratigraphy of the area. Seismic is correlated with the formation tops encountered in the wells. Interpretation was done by picking horizons in Kingdom. Major faults were picked on the dip lines and their parts were correlated across the dip lines to map the structures throughout the area.

3.4 Synthetic Seismogram

Synthetic seismogram is a seismic trace created from sonic and density logs and is used to compare original seismic data collected near the well location (Onajite, 2014).

The primary well data required to generate synthetic seismic trace is sonic log and density log (Herron, 2011). The following procedure is adopted to generate synthetic seismogram:

- Multiply sonic and density log to obtain acoustic impedance log.

$$Z = \rho \text{ x } v$$

Where Z = Acoustic impedance, ρ = density log and v = sonic log.

- Now compute reflection coefficient for each interface using Zeoppritz Equation:

$$R_i = \frac{Z_{i+1} - Z_i}{Z_{i+1} + Z_i}$$

- In the last step convolve source wavelet with the reflection coefficient to compute seismic trace.

$$S(t) = S(w) * RC$$

Where S(t) = Synthetic seismic trace, S(w) = source wavelet and RC = Reflection coefficient.

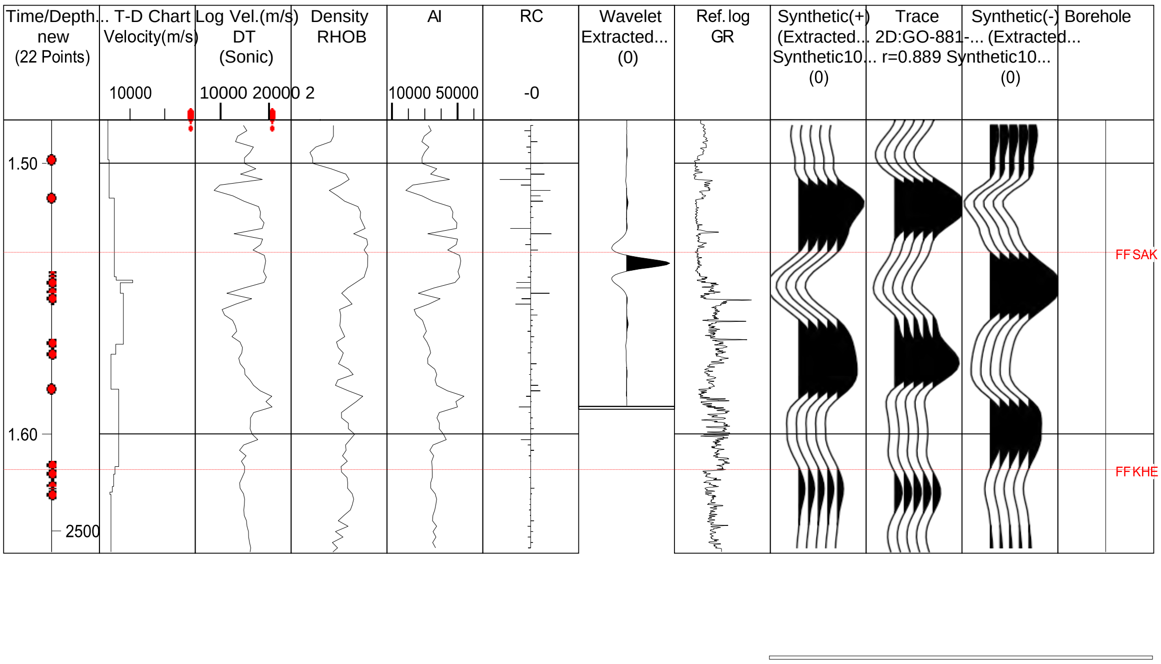


Figure 3.2 Synthetic Seismogram of Amirpur-01

3.5 Interpreted Seismic Section:

Procedure of seismic interpretation is very simple. It includes the identification of reflectors, marking of reflectors, identification of faults. Depth and time contouring of different marked horizons picking was made relatively easy by the integrated depth tool for SMT kingdom. Marked section of the line 782-CW-27,782-CW-24 881-CW – 11 and 782-CW-28 are shown below

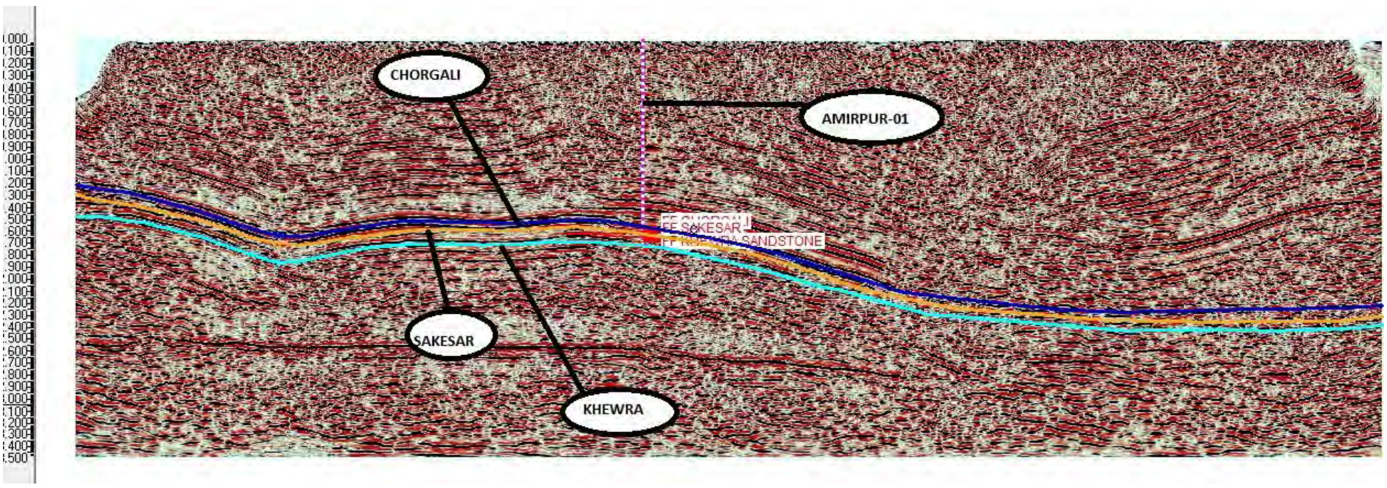


Figure 3.2 Marked section of Line 881-CW-11

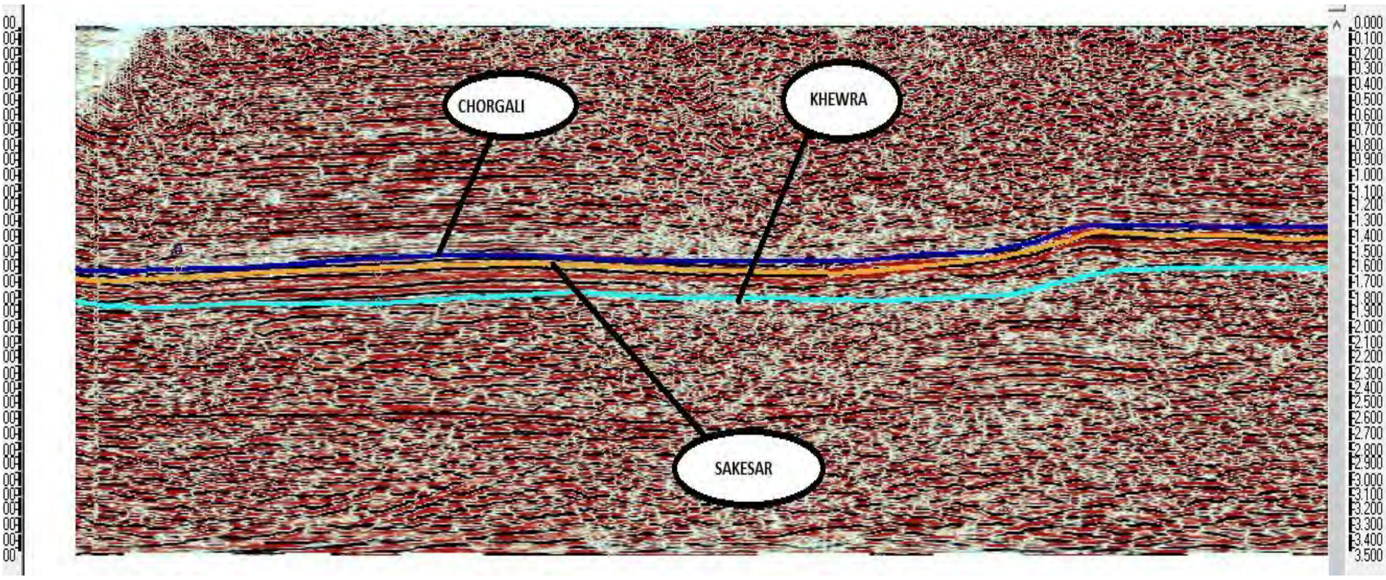


Figure 3.3 Marked section of Line 782-CW-28

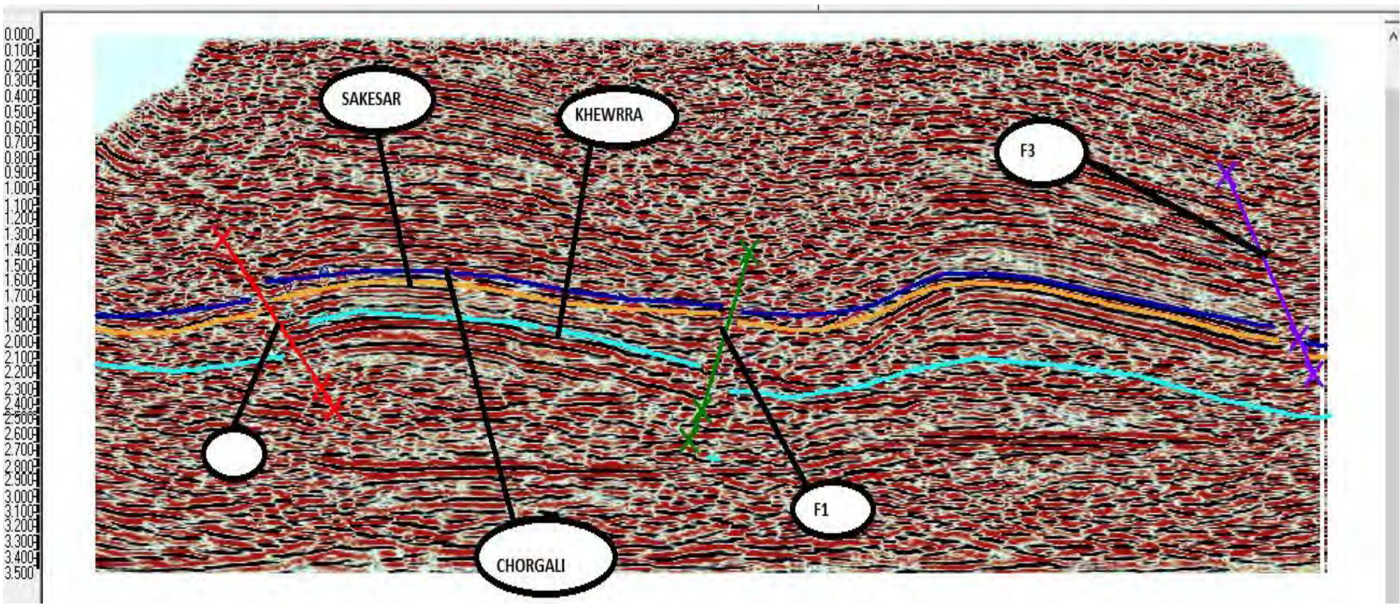


Figure 3.4 Marked section of Line 782-CW-24

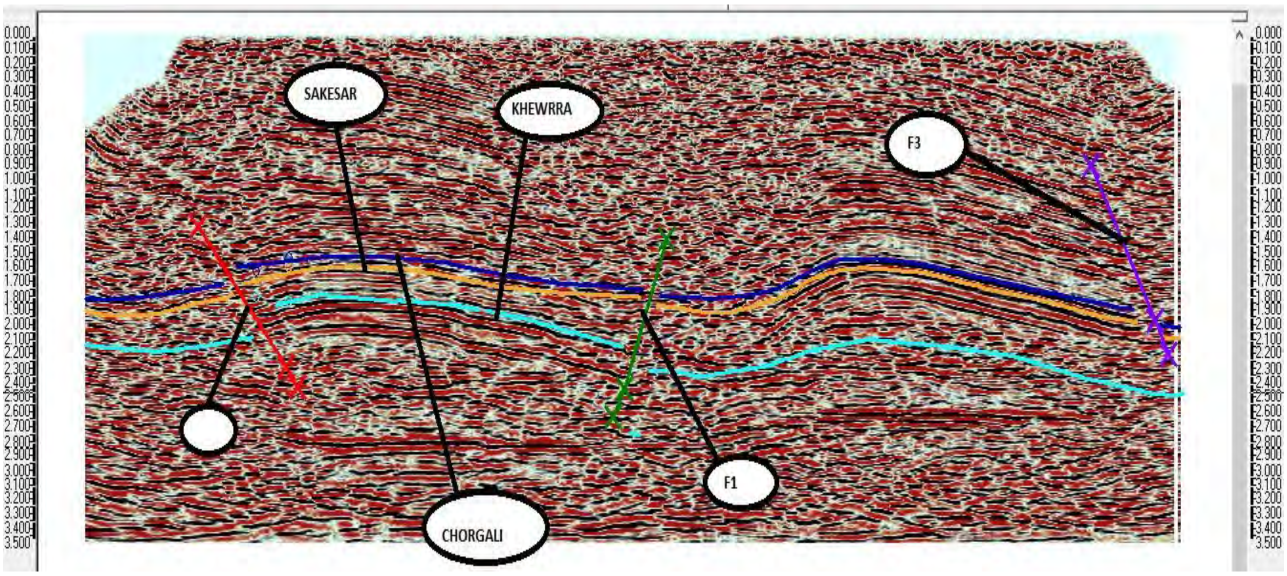


Figure 3.5 Marked section of Line 782-CW-27

3.6 Interpreted Seismic Time Section:

The time section gives the position and configuration of reflectors in time domain. We input the CDP/Shot point numbers and time information in the SMT Kingdom using the graphics interface. The main reflectors marked on the seismic section that are interest are Chorgali, Khewra and Sakesar Formation. It is very difficult and time consuming to mark the horizons manually on hard seismic sections. The interactive tools in SMT kingdom made it much easier and efficient to work and me aged the picked horizons data much easier and efficient to mark and menage the picked horizon picked data

3.7 Time Section:

Time domain seismic is a robust and efficient process routinely applied to the seismic data (Yilmaz, 2001). Time Section is marked seismic section that consist of horizons and faults and with time as vertical and CDP's horizontal function. Three prominent seismic horizons and three faults are marked. The maximum and more visual vertical and horizontal separation (heave and throw) occurred in CW-24 and CW-27 due to present on the left most portion of the section resulting in Chak Naurung anticline probably be the most significant location from the exploration point of view throughout the section.

3.8 Contour Maps:

Seismic interpretation leads to the display of the essential information in the form of maps. This makes it an important part of the interpretation of the data. The seismic map is usually the final product of seismic exploration, the one on which the entire operation depends for this usefulness. Contours are made in order to show the trend of a parameter, which are lines of equal time or depth wandering around the map as dictated by the data (Coffin, 1986)

Contouring represents the three-dimensional Earth on a two-dimensional surface. The spacing of the contour lines is a measure of the steepness of the slope, the closer the spacing the steeper the slope. A subsurface structural map shows relief on a subsurface horizon with contour lines that represent equal depth below a reference datum or two-way time from the surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip and faulting and folding. The contours reveal the trend of time and depth of different horizons in the area. For the sake of exporting time and depth section of the seismic lines and navigation data of the lines are used. On the seismic section Chorgali and Sakesar reflection is very strong and very easy to locate. Time & depth contours of the chorgali and khewra Formation are shown below

3.9 Time Contour Map of Khewra Formation:

The time contour map of Khewra formation shows that time variations with respect to the depth in the study area as shown in Fig 3.8.From figure we can clearly see that the horizon has shallow depth in the central region and deeper in the adjoining areas. The trap configuration in the area is generally structural related to the thrust faulting and folding in the time contour map that central map that the central part consists of the broken anticlinal feature which is good up dip area for hydrocarbon accumulation.

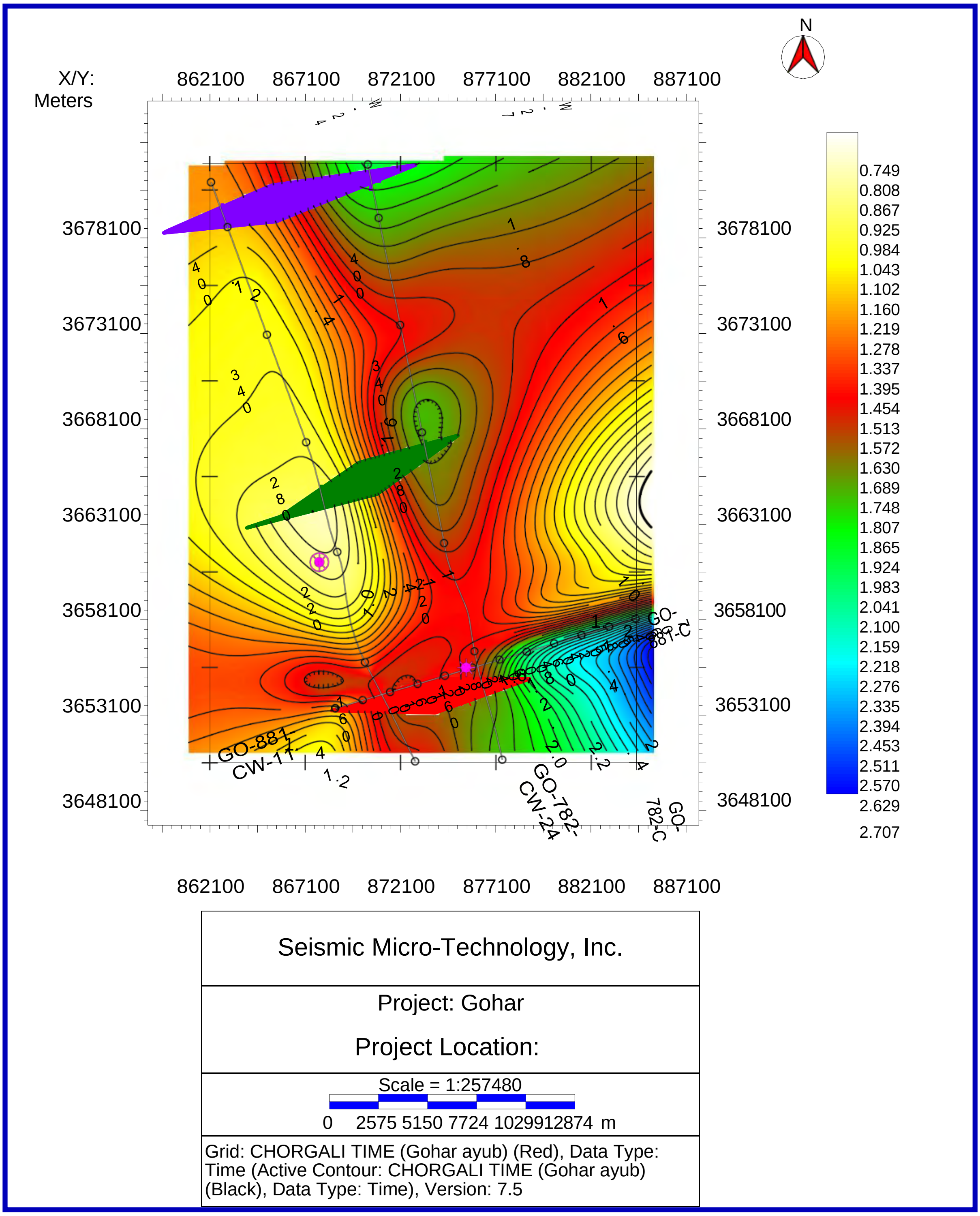


Figure 3.6 Chorgali time contour

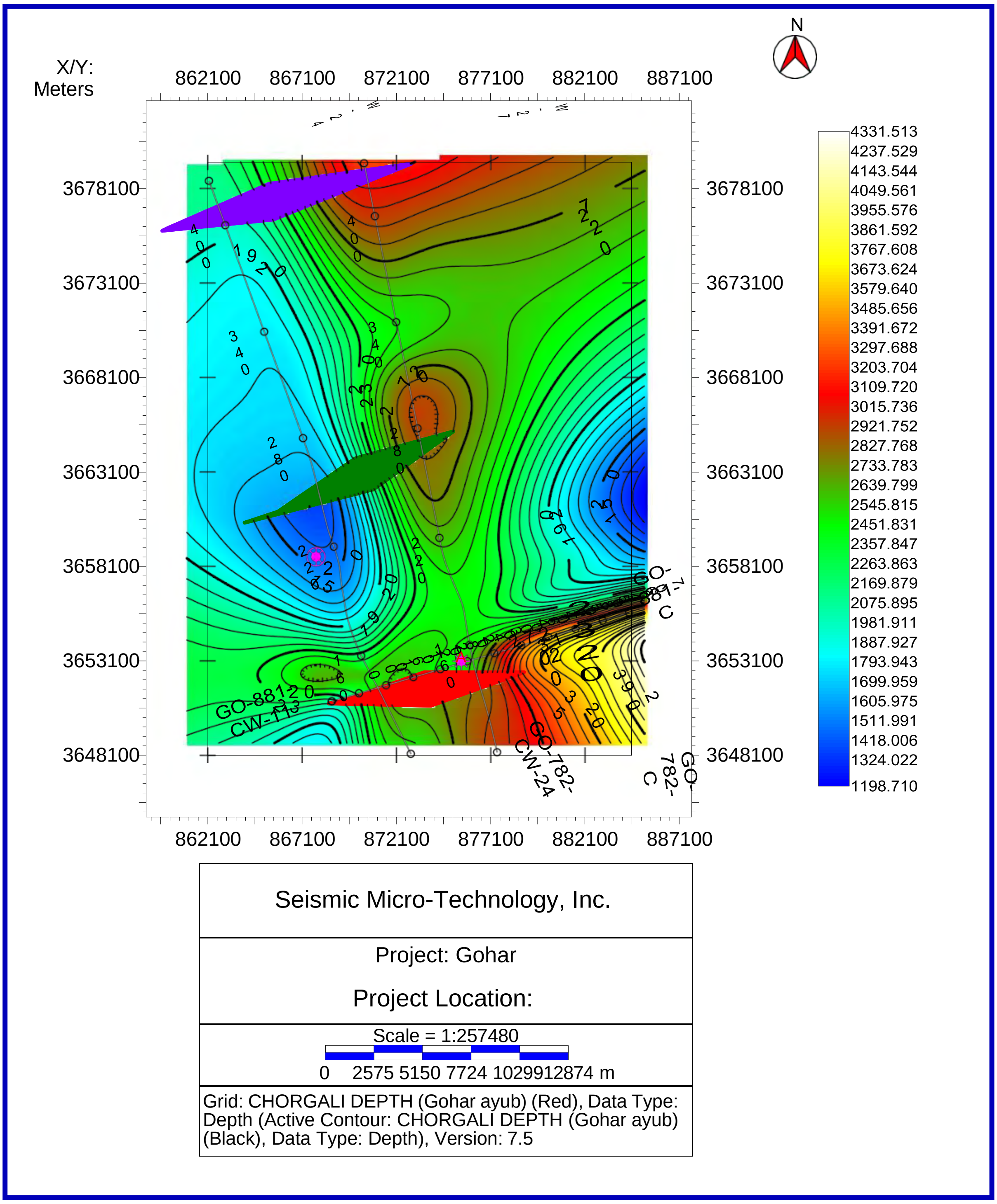


Figure 3.7 Chorgali depth contour

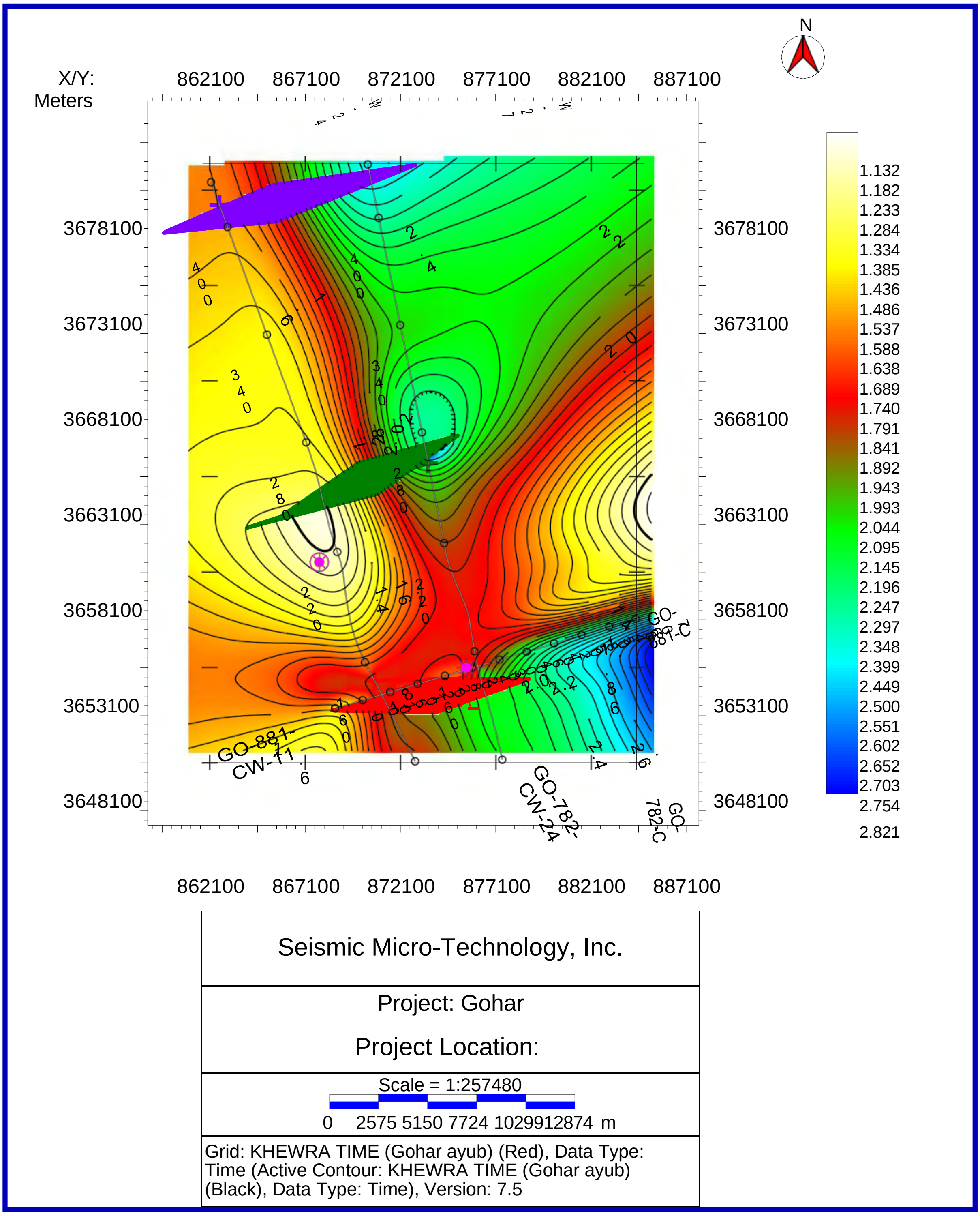


Fig 3.8 Khewra time contour

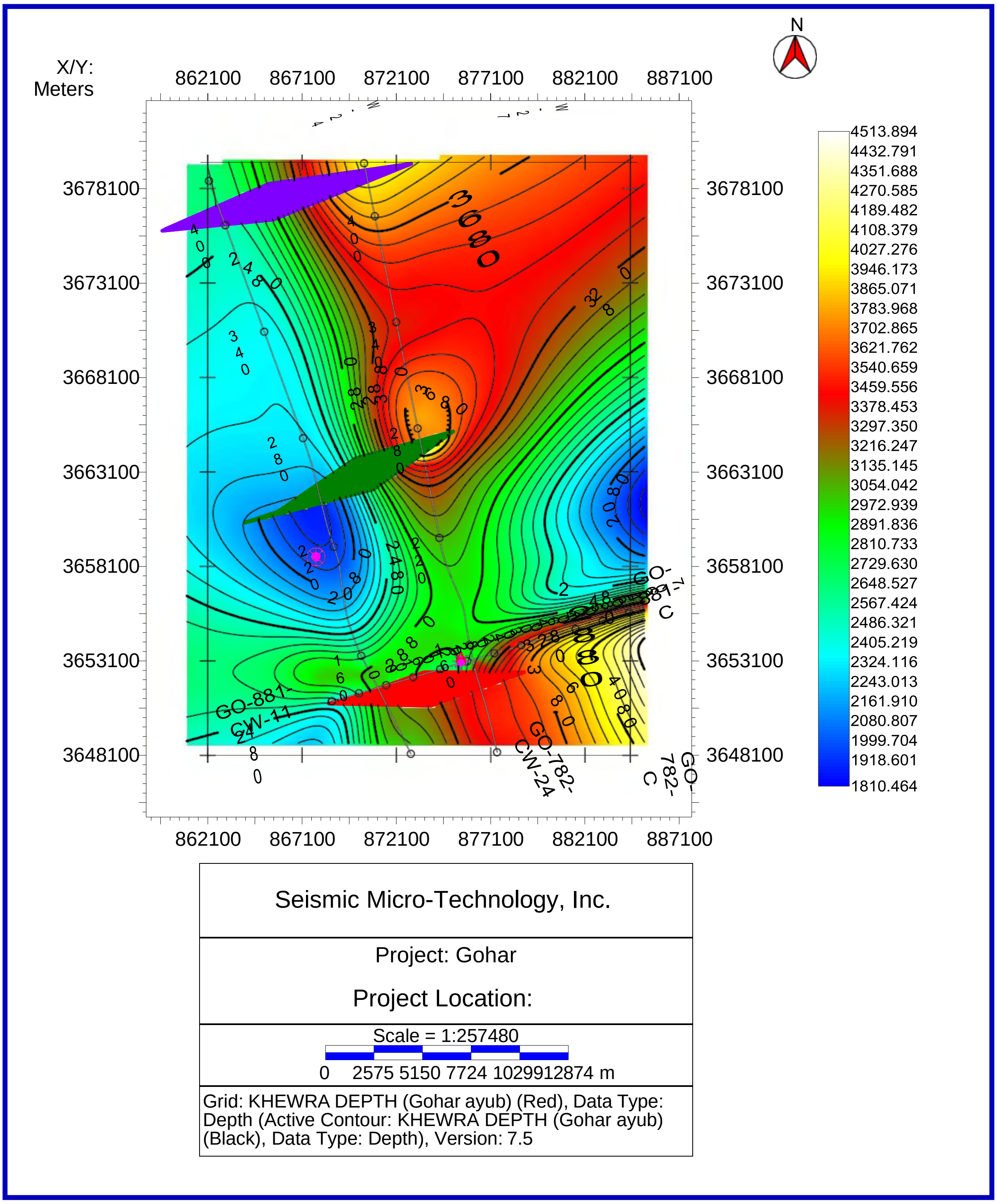


Figure 3.9 Khewra depth contour

CHAPTER 04 PETROPHYSICS

4.1 Petrophysical analysis:

The petrophysics analysis has been carried out in order to measure the reservoir characterization of the Chak Naurang area using the borehole data of Amirpur-01. We used the log curves including spontaneous potential log (SP), Gamma ray (GR), Sonic log (DT), Latera log deep (LLD), Latera log shallow (LLS), Neutron log, density log, Photo electric effect log (PEF).For petrophysics analysis the following parameters are calculated for reservoir rock.

- Volume of shale (by Gamma ray log)
- Porosity of reservoir (by SONIC, DENSITY and NEUTRON logs)
- Water saturation (by LLD, LLS and SP logs)
- Hydrocarbon Saturation (HCS)
- Permeability of reservoir rock (Ross Willey equation)

4.2 Estimation of volume of shale:

The volume of shale can be estimated from the response of Gamma ray log. The response of Gamma ray must be known through different lithologies. The gamma ray log is the passive logging because we measure the Formation properties without using any source. Actually, it is the measures the Formation 's radioactivity. The gamma ray emits from the Formation in the form of the Formation in the form of the electromagnetic energy which are called the photon. When photon collides with the Formation electron hence, they transfer the energy to the 31 Formation electron, so the phenomenon of the Compton scattering occurs. Now these emitted Gamma rays reached to the detector of the gamma ray and counted and displayed as count per second which is termed as the Gamma ray. The volume of the shale is calculated by using (Asquith and Gibson, 2004) equation given below.

IGR= (GR (log)-GR (min)/ (GR (max)-GR (min))

GR (max) = 100% shale

GR (min) = 0% shale or clean Formation.

The Gamma ray log shows maximum value when shale is encountered and shows a minimum value when clean lithology like sand is encountered. These values are calculated from given log response and then volume of shale is estimated by using (Asquith and Gibson, 2004) equation. The volume of shale calculated in FIMKASAR-02 well located in Chak Naurang area is 47%.

4.3 Estimation of porosity:

Porosity is the ratio of volume of voids to total volume of rock. Porosity is calculated for different zones of interest by using the following logs, sonic log, neutron log, density log.

4.3.1 Calculation of porosity from sonic log:

Sonic log device consists of a transmitter that emit sound waves and a receiver that picks and record the compressional waves as it reaches the receiver. This log is a recording verses depth of time (t) which is required by a compressional wave to go across 1 feet of Formation, called interval transient time Δt, while it is the reciprocal of the velocity of sound wave. This time (Δt) is depended upon lithology and porosity of the Formation (Asquith and Gibson, 2004). Sonic log can also be used for the following purposes in combination of other logs as given by (Daniel, 2004). Sonic log is also used in with combination with other logs to achieve our desired goals. The various combinations are given below.

a. Lithology identification (with neutron or density).

b. Synthetic seismogram (with density).

c. Mechanical properties of Formation (with density).

The mathematical relation used for calculating the porosity from sonic log is written be.

$$\varphi s = \frac{\Delta t_{log} - \Delta t_{mat}}{\Delta t_{fl} - \Delta t_{mat}}$$

The interval transient time of Formation increased due to presence of hydrocarbon known as hydrocarbon effect. This effect should be removed because it affects the values of calculated porosities.

4.3.2 Calculation of porosity from density log:

In the density logging gamma ray collide with the electron in the Formation and scattered gamma ray (Compton scattering) received on the detector which indicate the density of the Formation increase in the bulk density of the Formation causing the decrease in the count rate and vice versa. Bulk density which is obtained from the density log is considered the sum of the density of the fluid density and the matrix density of the Formation.

If rock type is known then porosity is calculated by using (Asquith and Gibson, 2004) equation. The rock lithology is known by using gamma ray log in this case it is limestone. The following relation is used for calculating porosity.

ϕd= Density Log porosity.

ρm= Density of matrix (limestone= 2.7)

ρb= Bulk density of formation ρf=

Density of fluid (salt mud = 1.1, Fresh mud = 1)

4.3.3 Calculation of porosity from neutron log:

This is the type of porosity log which measure concentration of Hydrogen ions in the Formation. Neutron is continuously emitted from chemical source in the tool of the neutron logging. When these neutrons collide with nuclei in the Formation and results in loss of some energy. Hydrogen atom has same mass as that of neutron, maximum loss of energy occurs when electron collides with hydrogen atoms. Hydrogen is an indication of the presence of the fluid in the Formation pores; hence loss of energy is related to the porosity of the Formation.

The neutron porosity is very low when the pores in the Formation are filled with the gas instead of the water and oil; the reason is that gas having les concentration of the hydrogen as compared to water and oil. This less porosity by the neutron PHI due to the presence of the gas called the gas effect (Asquith and Gibson, 2004).

4.4 Total porosity:

The total porosity is the sum of all the porosities calculated from different logs divided by the number of logs used for calculating porosities. The total porosity is calculated for the reservoir which is Chorgali in this case. The mathematical relation is used for this purpose is given below.

$$\varphi_T = \frac{\varphi_d + \varphi_n + \varphi_s}{3}$$

Φtotal= Average porosity.

4.5 Estimation of water saturation:

Water saturation is the percentage of pore volume in rock that is occupied by water of Formation. If it is not confirmed that pores in the Formation are filled by hydrocarbons, it is assumed that these are filled with water. To determine the water and hydrocarbon saturation is one of the basic goals of well logging. To calculate saturation of water in the Formation, a mathematical equation was developed by Archie shown below. All the parameters of Archie equation can be calculated from resistivity and spontaneous potential logs.

$$S_w = \left(\frac{R_w * F}{R_t}\right)^{1/n}$$

Rw = Resistivity of water.

Rt = True resistivity.

F = Formation factor.

n = Saturation exponent (value varies between 1.8 to 2.5)

ϕ = Effective porosity

m = Cementation factor constant = 2

a = 1

All the parameters of Archie equations are calculated by using different various logs discussed below.

4.5.1 Estimation of true resistivity:

Basically, there are different types of electrical Resistivity Logs. But in my work, I have only two logs available in my data which are simply explained as follow. These logs are used to measure the resistivity of the subsurface, but they measure the resistivity of the Formation fluids. They are very helpful to differentiate between water filled Formation and the hydrocarbon filled Formations. Resistivity logs include the following.

- Later log Deep (LLD).
- Laterolog shallow (LLS).

Laterolog Deep (LLD):

Laterolog deep is used for the deep investigation of the quietly undisturbed (Uninvaded zone) and it is called Laterolog deep (LLD). This log is also used for saline muds also in case of fresh mud. This log is generally used for measuring the Formation resistivity. It has deep penetration as compared to the (LLS).

Laterolog Shallow (LLS):

Laterolog shallow (LLS), used for shallow investigation of the transition zone / invaded zone. The depth of the investigation is smaller than the LLD.

These logs are used to calculate the true resistivity.

4.5.2 Estimation of resistivity of water:

The resistivity of water is calculated by Spontaneous potential log. The steps are discussed below the steps are discussed below

1. Pick SSP from S-P log by using formula given by (Rider, 1996)

SSP= SP clean – SP shale

SSP = Static spontaneous potential.

SP Clean= Spontaneous potential for sand.

SP Shale= Spontaneous potential for shale.

The value of SSP in OXY-01 is calculated to be -19 mv.

2. Determine the Formation temperature.

TF against the depth (d) using formula shown in equation given by (Rider, 1996).

$$T_f = \frac{d(BHT - T_{s)}}{T_D + T_S}$$

D =Depth of Formation (3250m).

Tf = Borehole temperature (820F).

Ts = Temperature at surface (260F).

TD = Temperature at depth.

3. Resistivity of the mud filtrate is calculated 0.48Ωm at surface temperature by using this relation.

$$R_{mf} = R_{mfe}(\frac{T_s + 6.67}{F_t + 6.67})$$

Where,

Ts = Surface temperature

Rmfe = Resistivity of mud filtrate equivalent.

Ft = Formation temperature.

4. Now resistivity of the mud equivalent (Rmfeq) is calculated by using Schlumberger chart shown in below figure 4.1

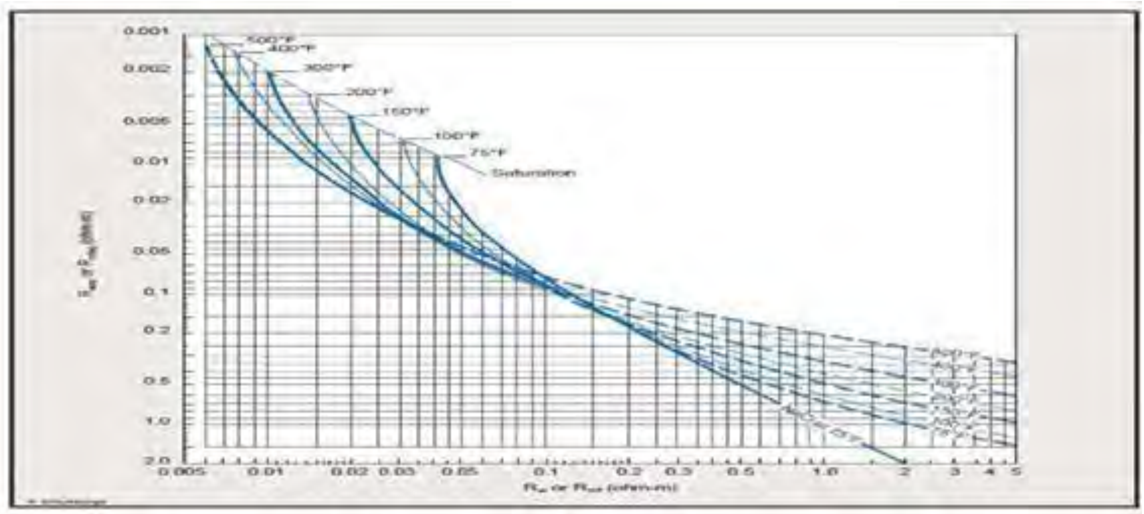
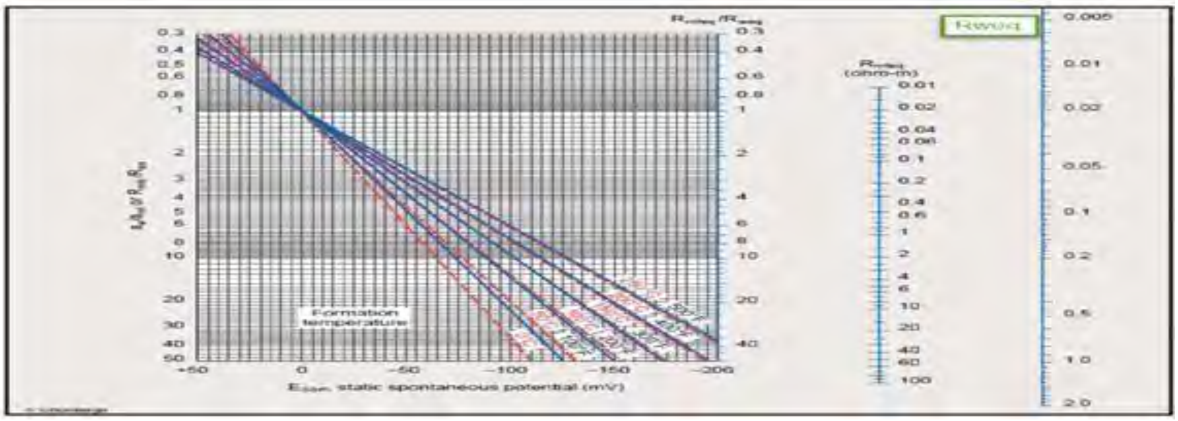


Figure 4.1 Schlumberger chart

5. Rweq (Water equivalent resistivity) is determined from the ssp (Static spontaneous potential).

6. This is the last step in this step the value of the resistivity of the water (Rw) is obtained against the value of the Rweq (Resistivity of the water equivalent) and Formation temperature.



4.6 Estimation of hydrocarbon saturation:

The fraction of pore spaces containing hydrocarbons is known as hydrocarbon saturation. The simple relation used for this purpose is given below.

$$Sw + SH = 1$$

The saturation of hydrocarbons is percentage of pore volume occupied by hydrocarbon.

Where,

SH = Hydrocarbon saturation and Sw = Water saturation.

4.7 Result

The petrophysical analysis of Amirpur-01 shows only one zone of interest marked from 2617-2622 meters. The petrophysical results show.

- Volume of Shale = 5.81%
- Effective porosity = 7.48%
- Water Saturation = 26.46 %
- Hydrocarbon Saturation = 73.34 %

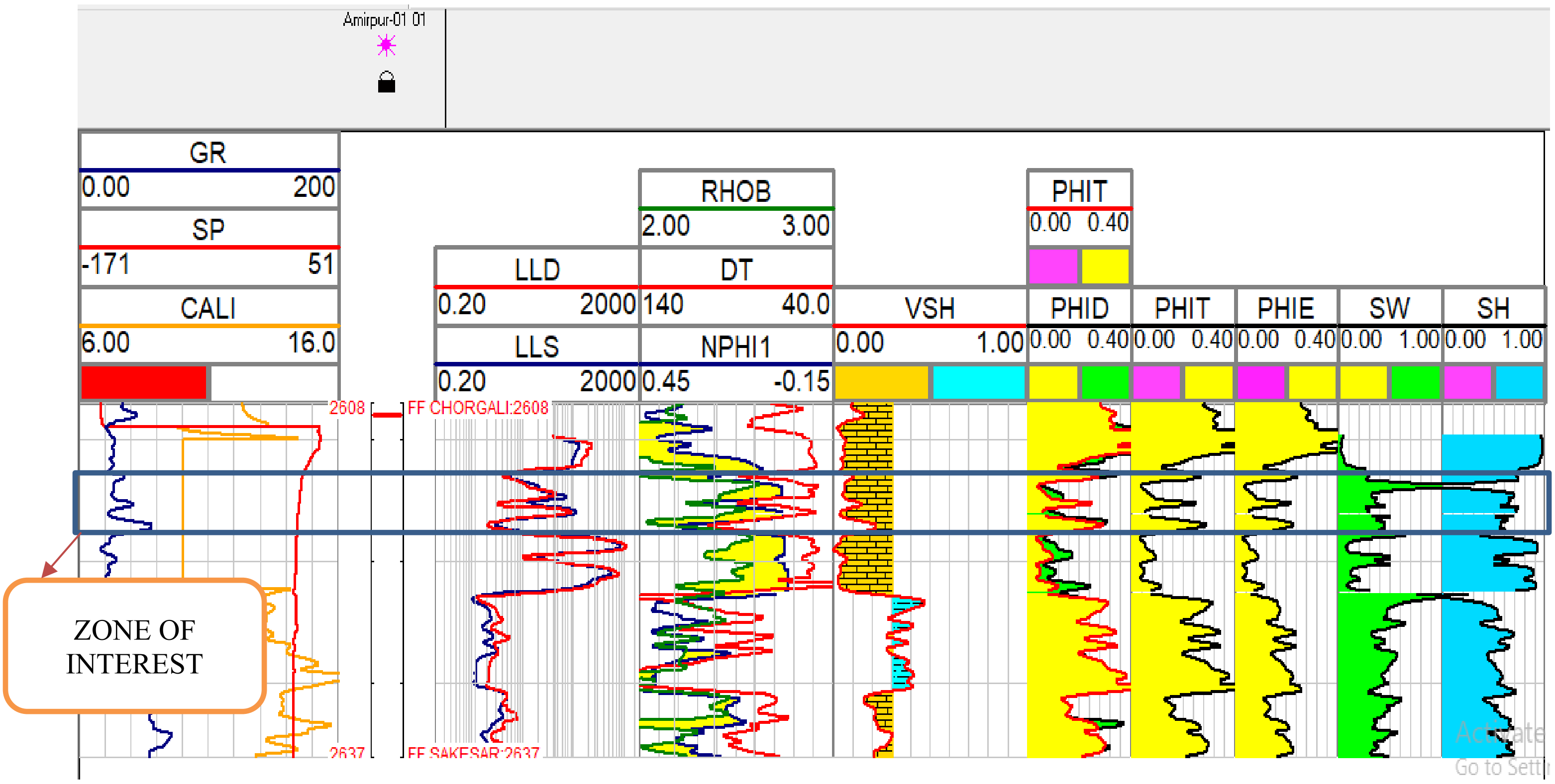


Figure 4.2 Petrophysical Analysis of Chorgali Limestone

CHAPTER 05

ROCK PHYSICS

5.1 Introduction

Quantitative Seismic Interpretation shows how rock physics can be functional to predict different parameters of reservoir, such as pore fluids and lithologies, from seismically resulting attributes. It demonstrates how the multidisciplinary combination of rock physics models with seismic data, sedimentological information and stochastic techniques can lead to more powerful results than can be obtained from a single technique. This provides an integrated methodology and practical tools for quantitative interpretation, characterization of reservoirs in the subsurface and assessment of uncertainty, using seismic and well-log data. The aim, in preparing Quantitative Seismic Interpretation, is to aid illustrate the potent role that rock physics can play in integrating both the data and expertise of geology and geophysics for characterization of reservoir (Avseth et al., 2005).

The objective for this research is to prepare links between seismic and properties of reservoir more quantitatively. The Quantitative Seismic Interpretation includes the use of any seismic attribute for which there are specific models and relates them to different rock properties. This technique introduces primary rock physics relations, which help to quantify the fluid properties and geophysical signatures of rock. Since rock properties are outcome of geologic processes, the geologic trends of various seismic signatures are quantified.

Rock Physics describes a reservoir rock by physical properties such as porosity, rigidity, compressibility, properties that will affect how seismic waves physically travel through the rocks. Rock physics or engineering parameters have been computed using velocity data derived from the velocity functions. In the real earth velocity varies laterally as well as vertically. Thus, instead of using a regional averaged velocity function which only shows a vertical mean trend of the velocity with depth, velocity of DT log was used. The RMS and average velocities are not the true representative of a particular subsurface layer as they provide a vertically summed effect of all overlying layers rock properties.

5.2 Elastic Rock Properties

5.2.1 P-Wave and S-Wave Velocity

Sonic travel time of compressional wave is generally used as porosity tool for given lithology. VP-VS relations are keys to the determination of lithology from Seismic and Sonic log data as well as for direct seismic identification of pore fluids using e.g. AVO analysis with passage of time as the waves go deeper, its values are decreasing. Introducing shear wave travel time is very helpful in determining mechanical rock properties. It is found that compressional wave is sensitive to the saturating fluid type. The use of the ratio of compressional wave velocity to shear wave velocity, Vp/Vs, is a good tool in identifying fluid type.

Lower values of P-wave and S-wave velocities show the shaly material or fluid substitution and higher values consolidated material. Seismic velocity increases with depth due to compaction of rocks, because of overburden pressure of rocks. S-wave velocity is best indicator of fluids, as these waves cannot pass through fluids.

From DT log, which has trainset time in μs/ft, we have calculated P-wave velocity in m/s using below formula

$$V_p = \frac{10^6}{3.28 \times DT} \qquad (5.1)$$

5.2.2 S-wave velocity

S-Wave velocity in m/s has been calculated from P-wave velocity using formula. Castagna suggests a different formula for Vs depend upon the lithology but it is not reliable for reservoir characterization. I use the formula given by Castagna in 1993 for limestone.

$$Vs = \frac{V_p}{1.9} \qquad (5.2)$$

5.2.3 Density

A very important property of a rock is density. The density of the material directly affects the P wave velocities passing through it. Lower values of density show the shaly material or fluid substitution and higher values consolidated material.

$$\boldsymbol{\rho} = 0.31 \times (V_p)^{0.25} \quad (5.3)$$

5.2.4 Bulk Modulus

The bulk modulus (K) of a substance measures the substance's resistance to uniform compression. It is the ratio of volume stress to volume strain. It describes the material's response to uniform pressure. For a fluid, only the bulk modulus is meaningful. Bulk Modulus will be low where greater the volume of shale in other words the density would be high. Lower values show the shaly material or fluid substitution and Young Modulus

Young's modulus or modulus of elasticity (E) is a measure of the stiffness of an isotropic elastic material. It is the ratio of the uniaxial stress over the uniaxial strain in the range of stress in which Hooke's Law holds. It describes the material's response to linear strain. Young Modulus will be high where greater the volume of shale because it is linear strain. Lower values show the shaly material or fluid substitution and higher values consolidated material.

$$E = \frac{9K\mu}{3K+\mu}$$

5.2.4 Shear Modulus

Shear modulus or modulus of rigidity (μ) is defined as the ratio of shear stress to the shear strain (angle of deformation). Lower values show the shaly material and higher values stiffer material. Shear Modulus is good indicator of fluid presence because fluids have zero value of Shear Modulus.

$$\mu = V_s^2 \times \rho \qquad (5.5)$$

5.2.5 Poisson ratio (σ)

The ratio of the transverse strain (relative contraction strain normal to the applied stress) to the longitudinal strain (relative extension strain in the direction of the applied stress).

$$\sigma = \text{Transverse Strain / Longitudinal Strain} \qquad (5.6)$$

Standard value for a limestone is 0.18-0.33GPa

5.2.6 Vp/Vs Ratio

It is the ratio between the primary wave velocities to the secondary wave velocity and calculated simply by dividing by Vp by Vs. Lower values of P-wave and S-wave velocity ratio show the shaly material and higher values stiffer material.

5.2.7 Acoustic Impedance (Z)

Acoustic impedance is the product of primary wave velocity and density of the rock.

Mathematically it can be written and calculated by the formula:

$$Z = Vp \times \rho \qquad (5.7)$$

5.2.8 Shear Impedance

Shear impedance is the product of the secondary wave velocity and density. Mathematically it can be written calculated by the formula

$$\text{Shear impedance} = V_S{}^2 \times \rho \qquad (5.8)$$

5.3 Results and Discussion

The rock physics parameter computed from P-wave velocity are shown in figure 5.1

Rock Properties in Sui

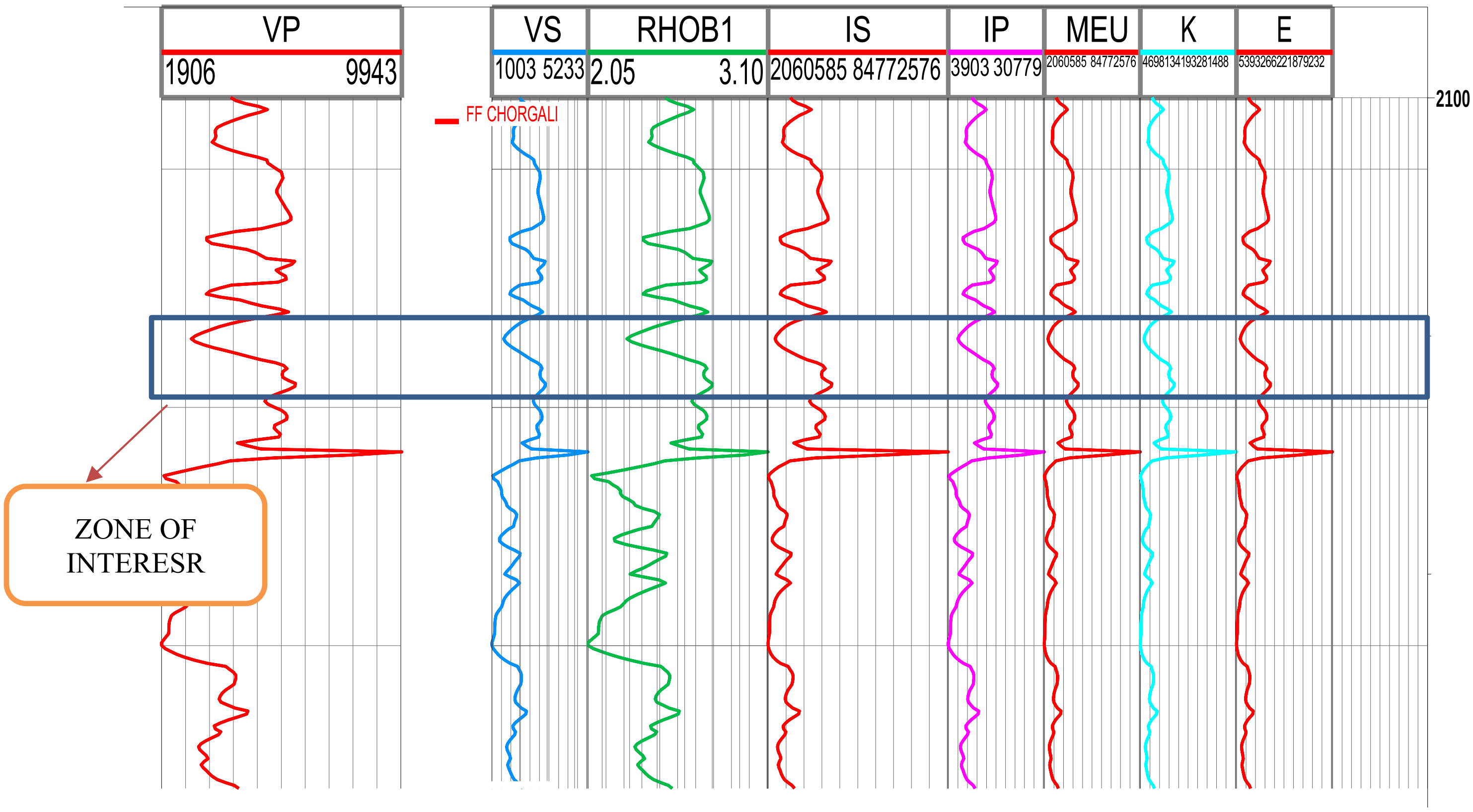


Figure 5.1 Elastic Properties of Chorgali

In the presence of hydrocarbon density and velocity can decrease and this is what happening in our zone of interest and this can be confirmed from the results of the Vp, Vs and density which decrease in our prospect zone.

The moduli (young, bulk and shear modulus) decrease in the perspective zone which indicate the presence of hydrocarbon; hence they give an idea about the presence of hydrocarbons.

P-impedance and S-impedance decrease in our area of interest hence indicate

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The moduli (young, bulk and shear modulus) decrease in the perspective zone which indicate the presence of hydrocarbon; hence they give an idea about the presence of hydrocarbons.

P-impedance and S-impedance decrease in our area of interest hence indicating the presence of hydrocarbons present here.

CONCLUSIONS

- ❖ Three Horizons Chorgali, Sakesar and Khewra are marked on seismic section by correlating Well data with Seismic data.
- ❖ Three faults are marked based on break in seismic reflection. All the three faults are reverse in nature indicating the study area in the Compressional Regime.
- ❖ Time and depth contours are prepared which confirms that the central region is shallower than the lobes area indicating the anticlinal trap.
- ❖ Petrophysical analysis of Chorgali Limestone proven a potential reservoir indicating 5.8% volume of shale, 7.5% effective porosity, 74% hydrocarbon saturation and 26% water saturation.
- ❖ Elastic logs also drop on the zone of interest indicates the presence of hydrocarbons and confirms the petrophysical results of study area.

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